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TO Mr. A. P. Huber
LOCATION Building K-1001

DATE February 18, 1953

ANSWERING LETTER DATE

ATTENTION

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SUBJECT Specifications for SF Material Discard

KP-434

QA Clerk TWS 1/26/95

Specifications for discarding uranium-containing waste materials from the batch recovery processes in K-131 and K-1410 on a continuing basis have been developed and are presented in the attached report. These specifications have been based on the economics of the processes and have been derived on the basis of an economic balance of uranium recovery costs versus established "values" of uranium at various isotopic assays. The uranium "values" are based on the value of top product-assay uranium set at $50.40 per gram by the Atomic Energy Commission.*

This report summarizes these specifications and the basic assumptions which were required in their derivation. The application of such specifications will result in a marked improvement in the economic efficiency of the aforesaid recovery processes without any loss in the reliability of material accounting controls.

Material to be discarded should be stored for possible reprocessing at other Atomic Energy Commission installations provided the economics and suitability of the processes so permit. Material not stored will be discarded in accordance with prevailing standards of health and safety.

*Sapirie, S.R., Projected Unit Cost Data, United States Atomic Energy Commission, Oak Ridge, Tennessee, July 15, 1952, ORO 20520 (Secret), letter to Mr. C.E. Center, Carbide and Carbon Chemicals Company, Oak Ridge, Tennessee.

Since these discard limits are based on the economics associated with the operating units at K-131 and K-1410, the limits will be used only by these units and will be reviewed for revisions as improvements are made in the processes.

J. A. Parsons

IMMiller/kc

SPECIFICATIONS FOR SF MATERIAL DISCARD

Part I. Discard Limit Specifications for the Uranium Recovery Process at K-131: The materials to be discarded are weak nitric acid water solution (the uranium content of which has been substantially extracted and purified by a batch-wise solvent extraction operation), lime cake, and untreated waste solution. The weak acid solution is derived from two types of material charged to the process; waste solutions and lime cake, the latter resulting from concentrating very weak solutions by a lime floccing operation.

The practicability of uranium recovery is wholly influenced by the extraction operation, which extracts smaller successive increments of uranium with each successive extraction. Table I indicates discard limit specifications for weak acid water solutions, lime cake, and untreated solutions for various uranium 235 assay ranges. Solutions and lime cake having uranium concentration below these specifications would be discarded.

It should be noted that at the lowest assay ranges listed the weak acid water solutions derived from very dilute uranium solutions may be discarded at higher assays than weak acid water solutions derived from dilute uranium solutions and lime cake. This amounts to a higher discard limit for low assay waste solutions having very dilute solutions as the parent material. The higher discard limit is due to the additional fixed cost involved in concentrating very dilute solutions by means of the lime floccing process and to the fact that discard limit concentrations are more sensitive to variations in fixed costs at the lower assays.

A brief description of the recovery process at K-131, together with the method of deriving these discard limit specifications, is presented in Appendix A of this report.

Table I - Discard Limit Specifications

For the K-131 Recovery Process

Parent Material:-	Discard Limit Concentrations				
	Weak Acid Water Solutions		Dilute Solutions, ppm U	Lime Cake, g U/g x 10^6	Very Dilute Solutions, ppm U
	Dilute Solutions and Lime Cake, ppm U	Very Dilute Solutions, ppm U			
Assay Range, Wt. Fraction U-235					
0.50 and above	0.5	0.5	1.0	<10*	0.1
0.25 to 0.50	1.0	1.0	2.0	<10*	0.15
0.10 to 0.25	2.0	2.0	3.5	<10*	0.25
0.05 to 0.10	6.0	6.0	11	21	0.75
0.02 to 0.05	15	15	26	52	2.00
0.01 to 0.02	100		175	400	
0.015 to 0.02		100			15
Below 0.01	All		All	All	
Below 0.015		All			All

* The discard limit concentration is indefinite due to the inability to analyze accurately at such low concentrations.

Part II. Discard Limit and Economic Limits of the Uranium Recovery Process at K-1410: The material to be discarded is contaminated waste solutions which result from the decontamination of process equipment and which have not been processed for uranium recovery at K-1410. The discard limit specification for this material (as shown in Table II) was based upon the total unit fixed cost of the K-1410 uranium recovery process.

Table II

Discard Limit Specification for the K-1410 Recovery Process

Material	Discard Limit Assay, Wt. fraction U-235
Contaminated Waste Solution	0.0090

Solutions having assays below 0.0090 weight fraction would be discarded. Those with assays of 0.0090 and above would be processed for recovery.

Because of the high incremental cost of uranium recovery at K-1410, material from this recovery process will be reprocessed at K-131 for further uranium recovery in accordance with the discard limit specification for K-131 as presented in section I of this report.

This material is ammonia-water solution the uranium content of which has been substantially removed by a precipitation process. The ammonia solution is derived from contaminated waste solutions resulting from the decontamination of process equipment.

The practicability of uranium recovery is wholly influenced by the precipitation process, which precipitates smaller successive increments of uranium with each successive precipitation. Table III indicates economic limits in terms of the uranium concentration of the ammonia-water solution after the first precipitation, ppm, for various uranium 235 assays. It would be uneconomical to further process uranium concentrations below these limits by precipitation.

Table III

Economic Limits of Uranium Recovery
from Ammonia-Water Solutions in the
K-1410 Uranium Recovery Process

Wt. Fraction U-235	Uranium Concentration in the Ammonia Solution after the First Precipitation, ppm.
0.930	10.2
0.649	15
0.386	25
0.194	50
0.107	100

It is readily apparent that these economic limits are considerably higher than the discard limit specifications for K-131. For this reason, contaminated waste solutions will be given one precipitation treatment at K-1410, then discarded or reprocessed at K-131 where the uranium will be further removed until the discard limit specification appropriate to the assay of the material is reached.

A brief description of the recovery process at K-1410 together with the method of deriving the discard limit and economic limits, is presented in Appendix B of this report.

Appendix A

Method of Deriving Discard Limit Specifications for the Uranium Recovery Process at K-131

Uranium contaminated water solution or lime cake* is charged to a dissolver which prepares the solution for solvent extraction. The solution or lime cake in the dissolver is acidified with nitric acid, and the resulting weak acid solution is filtered and sent to the extractor. The uranium in the solution is extracted batch-wise with a mixture of 15% tributyl phosphate and 85% Varsol, the number of extractions dependent upon the final concentration desired in the aqueous phase. The purified uranium is backed out of the solvent with water, and ammonia is added to precipitate the uranium from the water solution as ammonium diuranate. The precipitate is filtered, calcined to uranium oxide, ground, and fluorinated to uranium hexafluoride at K-1401.

Unit cost estimates in dollars per gram have been based on actual process costs and uranium yields and include charges for direct and indirect labor, direct and indirect materials, sample analyses, and overhead -- the latter figure as 100% of direct and indirect labor. These process costs cover the entire recovery process from the initial contaminated solution to the final product, uranium hexafluoride. Process costs do not include the cost of decontaminating the equipment since this must be done regardless of whether the uranium is recovered. Unit costs were divided into unit fixed costs and unit variable or incremental costs, the latter applying to the extraction operation. For dilute uranium solutions, the total fixed cost of recovery is distributed as follows:

Unit Operation or Process	Unit Fixed Cost, $/gram
Dissolving, Precipitation, and Reduction	0.174
Fluorination (at K-1301)	0.044
Material Handling	0.010
Total Unit Fixed Cost	0.228

In the case of processing very dilute uranium solutions, the unit lime floc cost is $0.172 per gram, making the total unit fixed cost $0.40 per gram.

---

* Lime cake is derived from the processing of weak uranium waste solutions with lime in order to concentrate the uranium, thereby easing storage problems.

The unit variable cost of the extraction operation is based on an average fixed cost of $11.85 per extraction divided by the incremental grams of uranium recovered per extraction. As an example and based upon experience, the incremental amount of uranium recovered per extraction was calculated as follows:

> An average initial uranium concentration of 4508 ppm in the aqueous phase and an average concentration of 64 ppm after the fourth extraction were used in the equation
>
> $$X_c = X_i D^i$$
>
> where X_c = initial uranium concentration in the aqueous phase, ppm
>
> X_i = uranium concentration in the aqueous phase after the i^{th} extraction, ppm
>
> D = constant
>
> i = number representing the i^{th} extraction

This equation follows from the Distribution Law. With the above average values of $X_c = 4508$, $X_i = 64$, and $i = 4$, $D = 2.90$

The incremental quantity extracted, ΔX_i, between the i^{th} and $i^{th} + 1$ extraction was then calculated by the equation

$$\Delta X_i = X_c\left(D^{-i} - D^{-(i+1)}\right)$$

Each total unit fixed cost was added to the variable cost of the extraction operation to obtain the corresponding unit incremental recovery cost, or the cost of processing each successive increment of uranium recovered in the extraction operation.

The results of the above calculations were plotted on log-log coordinates as incremental unit recovery cost, dollars per gram versus uranium concentration in the aqueous phase after the i^{th} extraction, ppm, resulting in the two curves shown in Figure 1 -- one for dilute uranium solutions and lime cake, and the other for very dilute uranium solutions.

Figure 1 was used in conjunction with Figure 2, which shows the relationship between the weight fraction of uranium 235 and the "value" of uranium as uranium hexafluoride, dollars per gram.*

*Sapirie, S.R., Projected Unit Cost Data, United States Atomic Energy Commission, Oak Ridge, Tennessee, July 15, 1952, ORO 20520 (Secret), letter to Mr. C.E. Center, Carbide and Carbon Chemicals Company, Oak Ridge, Tennessee.

The dollars per gram variable common to Figures 1 and 2 was eliminated to obtain the two curves shown in Figure 3 of economic limit, uranium concentration in the aqueous phase after the i^{th} extraction, ppm, versus the weight fraction of uranium^{235} in the material.

Economic limits are higher for weak acid solutions derived from very dilute uranium solutions at lower assays because of additional fixed cost involved in the lime floccing operation.

Assay ranges at various uranium concentrations were selected and stepped off as shown in Figure 3 to obtain the discard limit specifications presented in section I of this report. Such specifications are more convenient to apply than a curve.

The discard limit specifications for lime cake, and the two types of untreated solutions (dilute and very dilute uranium concentrations) were derived by relating the uranium concentrations of these materials with the weak acid-uranium water solutions derived from these materials as follows:

For each batch of lime cake processed in the dissolver, a ratio of the observed uranium concentration in the lime cake to that in the weak acid water solution was calculated. A mean of these ratios was then used as a factor to convert the discard limit uranium concentrations of the weak acid water solution to that of the lime cake. Discard limit concentrations of the untreated dilute uranium solutions were derived in the same manner.

Since very dilute uranium solutions are first concentrated by a lime floccing process, a ratio of the observed uranium concentration in the very dilute solution to that in the lime cake was calculated for each batch of solution so processed. A mean of these ratios was then used as a factor to convert the discard limit uranium concentrations of the lime cake to that of the very dilute solutions.

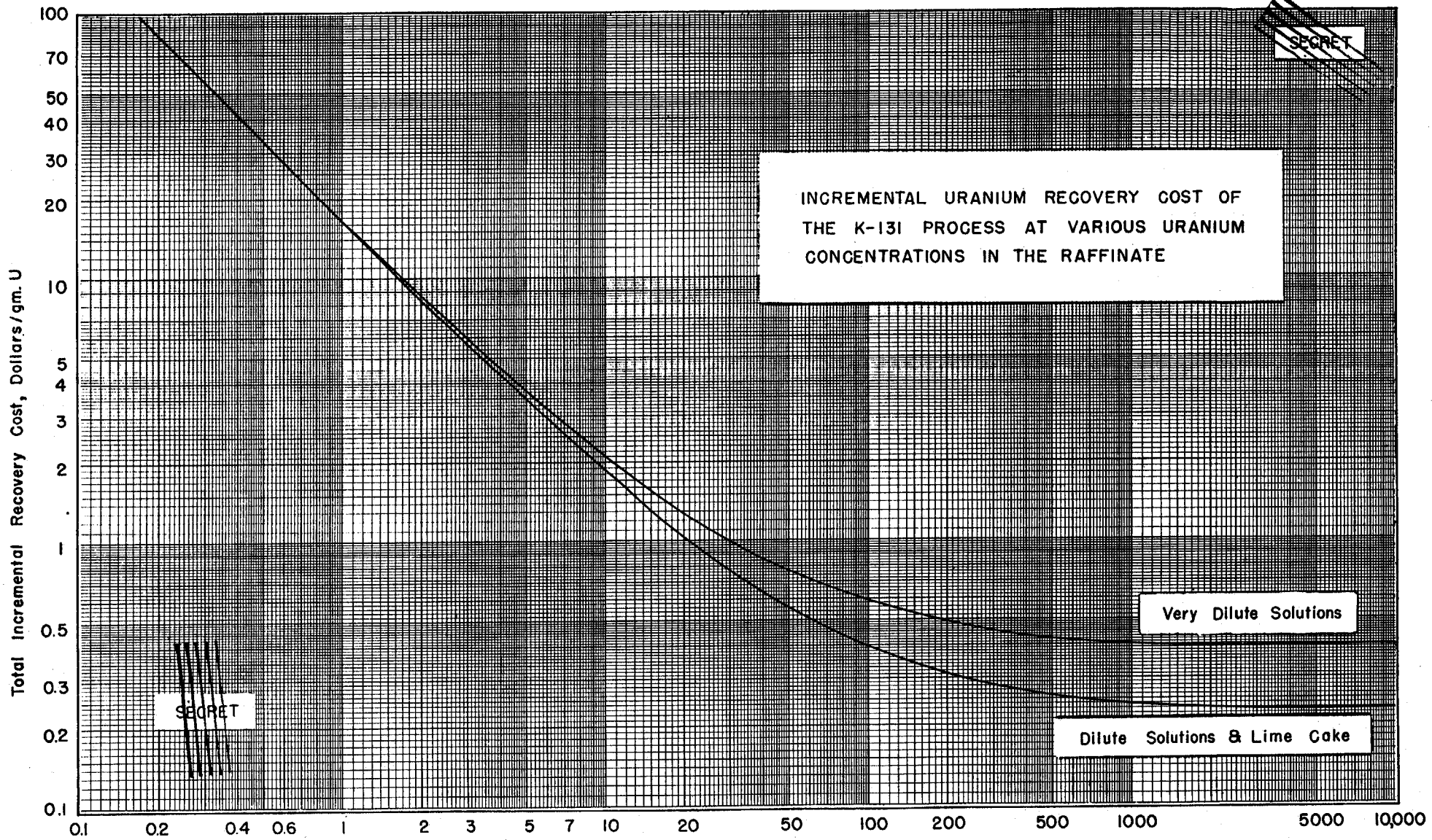
SECRET
INCREMENTAL URANIUM RECOVERY COST OF THE K-131 PROCESS AT VARIOUS URANIUM CONCENTRATIONS IN THE RAFFINATE
Very Dilute Solutions
Dilute Solutions & Lime Cake
SECRET
Total Incremental Recovery Cost, Dollars/gm. U
100
70
50
40
30
20
10
5
4
3
2
1
0.5
0.3
0.2
0.1
0.1
0.2
0.4
0.6
1
2
3
5
7
10
20
50
100
200
500
1000
5000
10,000
Uranium Concentration in Aqueous Phase after ith Extraction, ppm U

Figure 1.

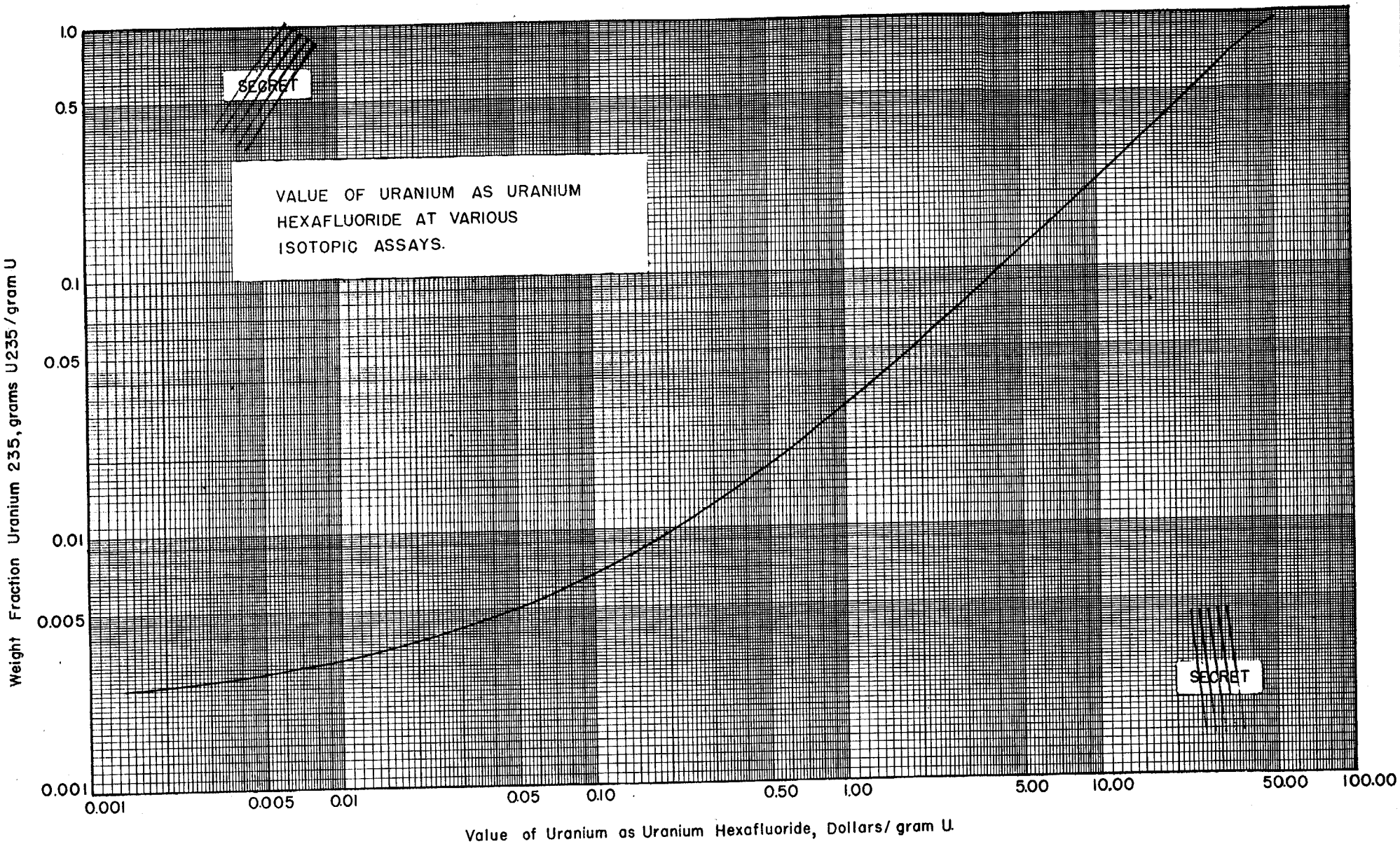
SECRET
VALUE OF URANIUM AS URANIUM HEXAFLUORIDE AT VARIOUS ISOTOPIC ASSAYS.
SECRET
Weight Fraction Uranium 235, grams U235/gram U
1.0
0.5
0.1
0.05
0.01
0.005
0.001
0.001
0.005
0.01
0.05
0.10
0.50
1.00
5.00
10.00
50.00
100.00
Value of Uranium as Uranium Hexafluoride, Dollars/gram U.

Figure 2.

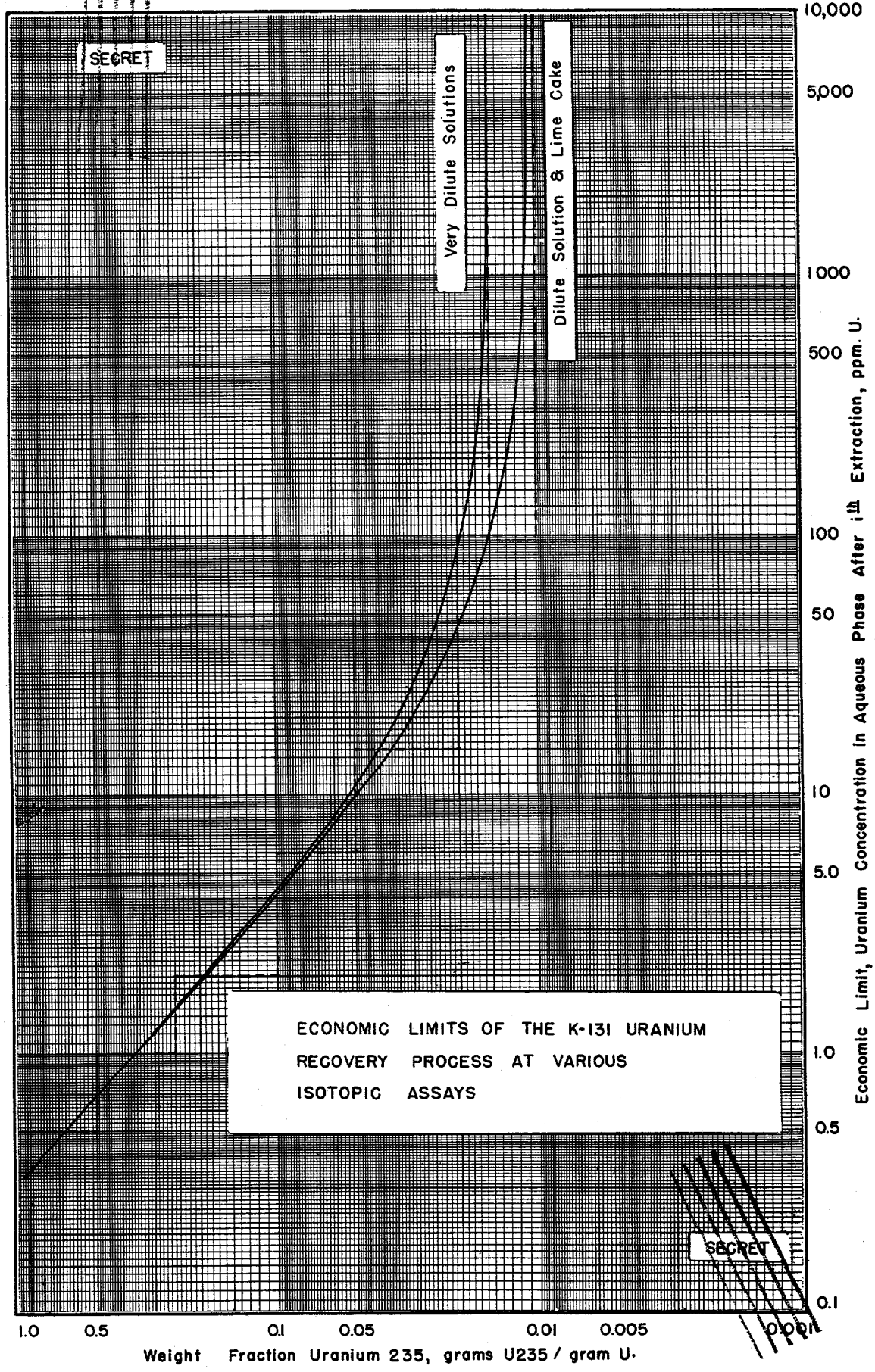
SECRET
Very Dilute Solutions
Dilute Solution & Lime Cake
ECONOMIC LIMITS OF THE K-131 URANIUM RECOVERY PROCESS AT VARIOUS ISOTOPIC ASSAYS
SECRET
10,000
5,000
1000
500
100
50
10
5.0
1.0
0.5
0.1
Economic Limit, Uranium Concentration in Aqueous Phase After ith Extraction, ppm. U.
1.0
0.5
0.1
0.05
0.01
0.005
0.001
Weight Fraction Uranium 235, grams U235 / gram U.

Figure 3.

Appendix B

Method of Deriving a Discard Limit and Economic Limits for the Uranium Recovery Process at K-1410

A uranium contaminated water solution containing peroxides and carbonates is charged to a digester which prepares the solution for precipitation. The solution in the digester is acidified with nitric acid, and the resulting unstable hydrogen peroxide and carbonic acid are removed with a fine bubble nitrogen "purge". Ammonia is then added to precipitate the uranium as ammonium diuranate, which is filtered, calcined to uranium oxide, and fluorinated to uranium hexafluoride at K-1301. The precipitation-filtration process is repeated for ammonia solutions having significant uranium concentrations after the first precipitation.

Unit cost estimates in dollars per gram have been based on actual process costs and uranium yields and include charges for direct and indirect labor, direct and indirect materials, sample analyses, and overhead -- the last figured as 100% of direct and indirect labor. These process costs cover the entire recovery process from the initial contaminated solution to the final product, uranium hexafluoride. Process costs do not include the cost of decontaminating the equipment.

Unit costs were divided into unit fixed costs and unit variable or incremental costs, the latter applying to the precipitation operation. The total unit fixed cost of recovery is distributed as follows:

Unit Operation or Process	Unit Fixed Cost, $/gm.
Acidification, Precipitation, and Reduction	0.136
Fluorination (at K-1301)	0.044
Materials Handling	0.010
Total Unit Fixed Cost	0.190

The above unit cost corresponds to a discard limit assay of 0.9% weight percent uranium 235 on the uranium value curve shown in Appendix A. This value was reduced to 0.90 as the discard limit specification in keeping with conservative discard practices.

The unit variable cost of the precipitation process is based on an average fixed cost of $23.32 per precipitation divided by the incremental grams of uranium recovered per precipitation. The incremental amount of uranium recovered per precipitation was

calculated as follows:

> The second precipitation reduces the uranium concentration in the ammonia solution to an average concentration of 2 ppm. Assuming various uranium concentrations after the first precipitation of 100 to 3 ppm, corresponding incremental amounts of uranium removed in the second precipitation were calculated.

This analysis was not applied beyond the second precipitation, since the incremental unit recovery cost would have far exceeded the top product uranium assay value of $50.40 per gram.

The total unit fixed cost was added to the variable cost of the precipitation operation to obtain the corresponding unit incremental recovery cost, or the cost of processing the increment of uranium recovered in the second precipitation.

The results of the above calculations were plotted on log-log coordinates as unit incremental recovery cost of the second precipitation, dollars per gram, versus uranium concentration in the solution after the first precipitation, ppm, as shown in Figure 4.

Figure 4 was used in conjunction with the curve presented in Appendix A of weight fraction uranium 235 versus the value of uranium as uranium hexafluoride, dollars per gram, in the same manner as that used in Appendix A. The dollars per gram variable common to both curves was eliminated to obtain the table shown in section II of this report -- economic limit, uranium concentration in the ammonia solution after the first precipitation, ppm, for various uranium assays.

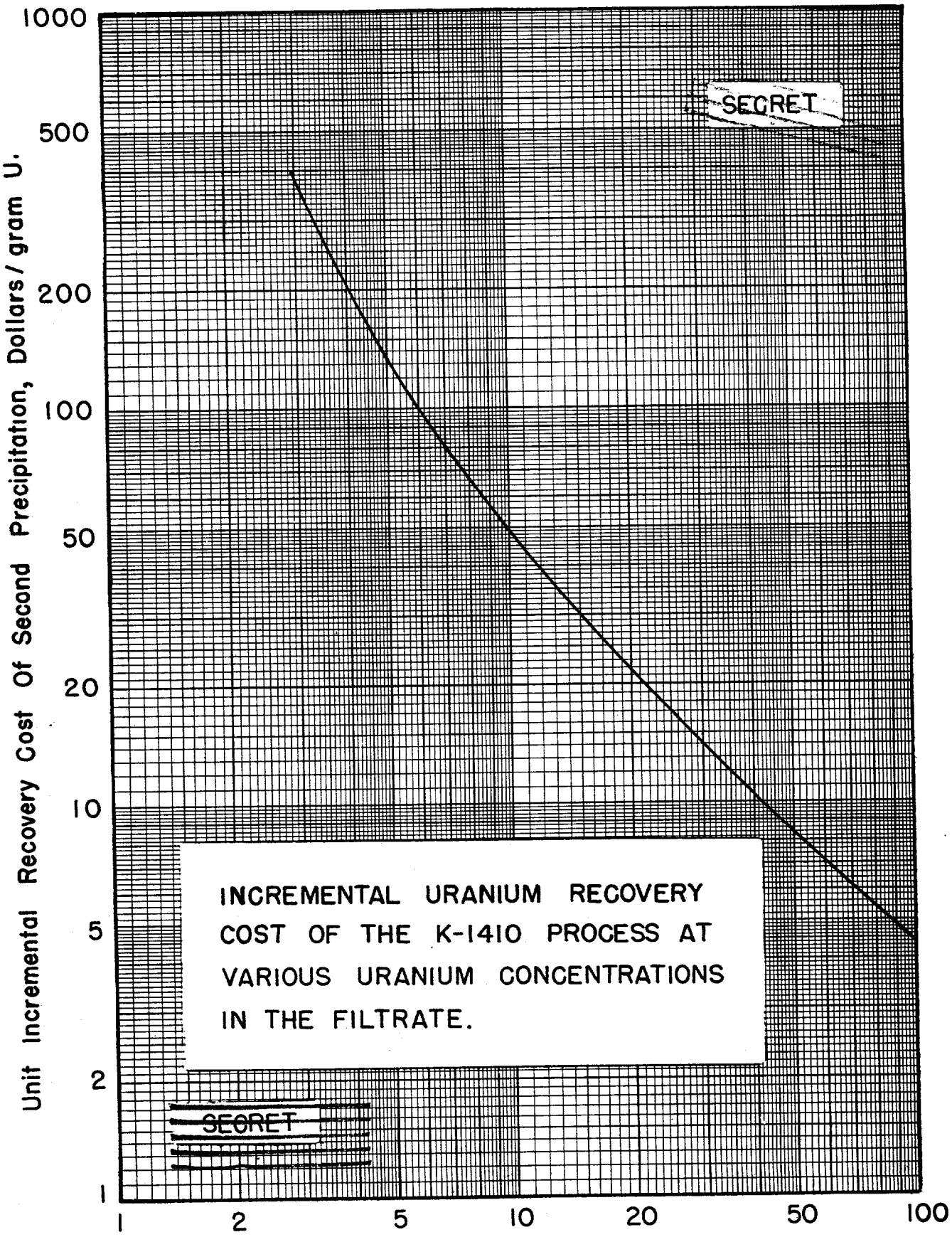
SECRET
INCREMENTAL URANIUM RECOVERY COST OF THE K-1410 PROCESS AT VARIOUS URANIUM CONCENTRATIONS IN THE FILTRATE.
SECRET
Unit Incremental Recovery Cost Of Second Precipitation, Dollars / gram U.
1000
500
200
100
50
20
10
5
2
1
1
2
5
10
20
50
100
Uranium Concentration After First Precipitation, ppm. U.

Figure 4